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Fabian Johannes Ballier

Systematic gripper arrangement for a handling device in lightweight production processes

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Editor: Prof. Dr.-Ing. Jürgen Fleischer
Prof. Dr.-Ing. Gisela Lanza
Prof. Dr.-Ing. habil. Volker Schulze

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von

Dipl.-Ing. Fabian Johannes Ballier

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Preface by editor

The fast and efficient implementation of innovative technologies is supported by the following factors. The globalization of the economy is the decisive economic factor for manufacturing companies. As "value-added partners", universities can make a significant contribution to the competitiveness of industry by developing scientific foundations, new methods and technologies as well as actively supporting the implementation process in practical applications. Against this background, this series of publications will report the current research results of the Institute of Production Engineering (wbk) at the Karlsruhe Institute of Technology (KIT). Our research work is concerned with increasing the performance of manufacturing processes, associated machine tool and handling technologies as well as with the holistic consideration and optimization of the entire production system. On the same time technological and organizational aspects are considered here.

Prof. Dr.-Ing. Jürgen Fleischer

Prof. Dr.-Ing. Gisela Lanza

Prof. Dr.-Ing. habil. Volker Schulze

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Preface by author

This work was created during my work as a research associate at the wbk Institute for Production Engineering of the Karlsruhe Institute of Technology (KIT) since March 2014.

First of all, I would like to thank Prof. Dr.-Ing. Jürgen Fleischer for taking over the main referent and for five years of successful cooperation. The freedom of decision that he grants to his research associate is one of the reasons why they have the opportunity to develop themselves professionally and personally. I would also like to thank my co-referent Prof. Dr.-Ing. Jill Urbanic for constructive discussions and the productive visit that I was able to experience in Canada, which helped me a lot in my dissertation.

My institute colleagues were an important support for me in the creation of this work, taking time for me despite having a full schedule. The friendly and open atmosphere of our institute is an important aspect of our success and I hope it will be preserved. I would also like to express my special thanks to the numerous staff members at the institute who make it possible for the research associates to work scientifically to this extent in the first place. In addition, I would like to thank the workshop employees, all colleagues in the IT, secretariats and finance department who take over a lot of the organizational work from us, which enables us to carry out our research. I think we all know that the scientific staff sometimes causes more chaos than necessary.

I would also like to mention my students who contributed to the success of this work. I would especially like to mention Michael Steinlein, Moritz Gegenbauer, Tobias Dmytruk, Uli Hörmann and Amal Abderrahman for their support.

Writing a dissertation always involves a great deal of time, which has a considerable influence on leisure activities. For this reason, such work is only possible if friends and family support this project which is not self-evident.

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I would like to thank my friends for understanding that I did not always have time for them. Furthermore, I have to thank my wife for the time she gave me to write my thesis and most importantly I would like to thank my parents who have always given me the right measure of freedom and support so that I can write these lines today. You have all been directly or indirectly involved in this work and have been an important part of my life. Thanks to all of you.

Karlsruhe, Dezember 2018

Fabian Johannes Ballier


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Abstract

Handling devices are an integral part of automated production processes. Nevertheless, they are generally regarded as non-value-adding and therefore their planning and projecting should be as effective as possible, with only a small amount of time and personnel expenditure. Still, they remain an important part of the process chain and they must meet certain conditions in this context. In order to ensure their functionality and invest little time in their project planning, handling devices are often oversized. Especially for flat parts, this results in heavy handling solutions where the weight of the object and the handling device are in a disproportionate relationship.

The objective of the present work is to automate the project planning of handling devices as much as possible. This process is presented using the example of the process chain for the production of lightweight parts using the sheet molding compound (SMC) and resin transfer molding (RTM) processes.

As a first step, a modular handling device is developed and built-up, which enables a large number of gripper arrangements. This device then makes it possible to measure the resulting deflection of flat parts in the handling process. In order to ensure that it is not always necessary to measure the deflections, a model is built-up with ABAQUS to enable a simulated estimation. Using this simulation model, a design logic for the arrangement of the grippers on any shaped parts is presented.

This design logic works in two steps and is based on the approach of growing neural gas (GNG), which is adapted to the problem by implementing additional rules. First, an initial gripper configuration is created based on the geometry of the object, which is then improved by an iterative process of simulation and adaptation. Since the production of lightweight parts often requires more than just one type of sheet, various solutions for the different sheets are combined systematically at the end to form one gripper arrangement and a method is shown concerning how this can be implemented using the previously developed modular handling device.

Kurzfassung

Handhabungsgeräte sind ein integraler Bestandteil automatisierter Produktionsprozesse. Dennoch werden sie in der Regel als nicht wertschöpfend angesehen, weshalb ihre Planung und Projektierung mit geringem Zeit- und Personalaufwand so effektiv wie möglich sein sollte. Gleichzeitig bleiben sie ein wichtiger Teil der Prozesskette und müssen in diesem Zusammenhang bestimmte Bedingungen erfüllen. Um ihre Funktionalität zu gewährleisten und wenig Zeit in die Projektierung zu investieren, sind Handhabungsgeräte oft überdimensioniert. Insbesondere bei flachen Teilen führt dies zu schweren Handhabungslösungen, bei denen das Gewicht des Handhabungsobjekts und des Handhabungsgerätes in einem Missverhältnis zueinander stehen.

Ziel der vorliegenden Arbeit ist es, die Projektierung von Handhabungsgeräten so weit wie möglich zu automatisieren. Dieser Prozess wird am Beispiel der Prozesskette zur Herstellung von Leichtbauteilen mit den Verfahren „sheet molding compound“ (SMC) und „resin transfer molding“ (RTM) dargestellt.

In einem ersten Schritt wird ein modulares Handhabungsgerät entwickelt und aufgebaut, das eine große Anzahl von Greiferanordnung ermöglicht. Mit diesem Handhabungsgerät kann dann die resultierende Durchbiegung von flachen Bauteilen mit verschiedenen Greiferanordnungen gemessen werden. Um sicherzustellen, dass es nicht immer notwendig ist die Durchbiegungen zu messen, wird mit ABAQUS ein Modell aufgebaut, das eine Simulation der Durchbiegung ermöglicht. Anhand dieses Simulationsmodells wird eine Designlogik für die Anordnung der Greifer entwickelt.

Diese Designlogik arbeitet in zwei Schritten und basiert auf dem Ansatz des „growing neural gas“ (GNG), das durch die Implementierung zusätzlicher Regeln an das Problem angepasst wird. Zuerst wird eine erste Greiferkonfiguration basierend auf der Geometrie des Objekts erstellt, die dann durch einen iterativen Prozess aus Simulation und Anpassung verbessert wird. Da die Herstellung von Leichtbauteilen oft mehr als nur einen Zuschnitt erfordert, werden am Ende systematisch verschiedene Lösungen für die verschiedenen Zuschnitte zu einer Greiferanordnung zusammengefasst und ein Verfahren gezeigt, wie dies ,mit dem zuvor entwickelten modularen Handhabungsgerät realisiert, werden kann.

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